Coll. Antropol. **38** (2014) 2: 559–563
Original scientific paper

# Sex Ratio at Birth in Croatia: Update

**Dario Pavić**

University of Zagreb, Department of Sociology, Center for Croatian Studies, Zagreb, Croatia

**A B S T R A C T**

*There is strong evidence that the sex ratio at birth is partially determined by environmental and social factors. The modern change in those factors serves as an explanation for the secular decline in sex ratio at birth in most of the industrialized countries. This article is the reexamination of the results from my previous communication in which no trend in sex ratio at birth was established for the Croatian data from 1946 to 2007. The data for the years 2008 to 2011 were added, which didn't result with the detection of a significant change in sex ratio at birth by the regression analysis or by the Box-Jenkins time series analysis. Although the numerous factors associated with the decline in sex ratio at birth did occur during the studied period (e.g. increased exposure to the environmental pollution through food, air and water, the rise of the obesity and diabetes incidence, the economic crisis etc.), it appears that none of them made the measurable impact on sex ratio at birth. Also, the possible marginally significant decline in sex ratio at birth could be the result of a high sex ratio at birth immediately after the World War II. The results of this study caution against rapid generalization of the factors found to influence the sex ratio at birth in the epidemiological and clinical studies on the population level data.*

***Key words**: sex ratio, Croatia, time series, regression*

## Introduction

Sex ratio at birth (the ratio of male live-births to female live births) is one of the most researched demographic phenomena, yet the straightforward explanation of its dynamics is still lacking. It has been shown that a multitude of ecological factors cause a departure from its average values in human populations: war[1,2], natural and other catastrophes[3,4], exposure to environmental chemicals[5], certain professions[6], tobacco and alcohol consumption[7,8], nutrition and obesity[9,10], pathological conditions[11], temperature and geographical latitude[12,13] etc.

Also the biased sex ratio at birth was observed within certain demographic categories. Sex ratio at birth is affected by parental age (in particular father's age[14,15]), birth order[16] and the season of birth[17,18]. Most of these studies indicate that the sex ratio at birth decreases (becomes female-biased) with respect to the adverse environmental and somatic conditions affecting one or both parents around the time of conception or during gestation. This conclusion is in accordance with the more general evolutionary theory of differential sex allocation and parental investment in offspring depending on parental condition[19].

Besides the factors affecting sex ratio at birth themselves, there has been a great interest in temporal variation of sex ratio at birth yearly values for certain countries and populations[20–23]. It has been suggested that sex ratio at birth values vary non-randomly across time, and that there is dependence between the successive sex ratio observations[24]. However, in the second half of the twentieth century a marked trend in both increase and decrease of sex ratio at birth yearly values was observed. The sex ratio at birth decreased in Northern and Eastern European countries, North America and Mexico, and increased in sex ratio at birth in Mediterranean countries, while remaining unaffected in some countries[22]. The temporal changes in sex ratio at birth most probably reflect the changes in ecological conditions and demographic structure of affected populations through time, although an unequivocal explanation is lacking.

In my previous communication I presented the results of the analysis of sex ratio at birth in Croatia from 1946 to 2007[25]. I failed to show any discernable trend in the data, although the results were only marginally non-significant. Considering the presence of the factors that

Received for publication July 11, 2013

might have affected sex ratio at birth in Croatia, I attributed the non-existence of the trend mostly to the small number of live-births for each year in Croatia and the relatively small number of sex ratio at birth yearly observations. In this article I re-analyze the data by including the newer data on sex ratio at birth in Croatia, using the same statistical methods as in the previous study. In this way I enlarge the sample of yearly data on sex ratio at birth and thus raise the probability of achieving statistical significance of the tests.

## Materials and Methods

The data on sex ratio at birth was collected from the vital statistics reports issued by the Central Bureau of Statistics of the Republic of Croatia for the years 1946 to 2011. As mentioned previously, there are some problems concerning the validity of data for the analyzed period. Although Croatia had the same borders from 1946 to 2011, during the Homeland war period (1991–1998) the Croatian authorities did not control the entire territory of the country. Furthermore, due to pre-war emmigration and wartime emigration and immigration, the data cannot be considered reliable. The change in methodology of the vital statistics reporting in 1998, also affects the reliability of data. Bearing all these difficulties in mind, the obtained yearly values of sex ratio at birth are considered to be the best ones available. The same methodology was used as in previous communication[25]. The Box-Jenkins time series analysis (ARIMA) was performed and the procedure for the univariate time-series analysis, defined by Cromwell et al.[26] was followed. The stationarity of the series was assessed by the augmented Dickey-Fuller test (ADF), and normality of the distribution of data was tested by the Shapiro-Wilk test. The independence of the series was assessed by the Ljung-Box test. Also, a linear regression with the control of autocorrelation was performed in order to discern the presence of a trend in the data, as well as its nature. The autocorrelation was tested with the Durbin-Watson test. The presence of the autocorrelation would have entailed the use of Yule-Walker estimates instead of the ordinary least square (OLS) estimates. Unlike the previous paper, I used the ratio of males to females as a measure of sex ratio because of the ubiquity of this measure in the literature.

## Results

During the observed period there have been 4 207 032 live births, of which 2 167 278 were males and 2 039 754 were females, with an average sex ratio at birth of 1.062. The most babies were born in 1949 (96 407) and the least in 2003 (39 668). The highest sex ratio at birth was in 1947 (1.084), while the lowest one was in 1994 (1.04). The total number of births declines from 1949 with some minor fluctuations (Figure 1).

The results of the Box-Jenkins time series analysis are shown in Table 1.

**TABLE 1**
RESULTS FOR THE TIME-SERIES TESTS OF THE CROATIAN SEX RATIO AT BIRTH DATA FOR THE YEARS 1946–2011

| Box-Jenkins time series analysis tests | | |
|---|---|---|
| **Stationarity test** | | |
| Augmented Dickey-Fuller test* | Tau | p value |
| | -3.9004 | 0.01961 |
| **Independence test** | | |
| Ljung-Box test | Q | p value |
| Lag 1 | 0.1992 | 0.6554 |
| Lag 2 | 0.207 | 0.9017 |
| **Normality of distribution test** | | |
| Shapiro-Wilk test | W | p value |
| | 0.9857 | 0.6489 |

* alternative hypothesis: stationary

As before, the results of the ADF test suggest that the series is stationary and needs no differencing in order to evaluate the series model. It also implies that the series exhibits a constant mean and variance over time and a lack of any type of deterministic trend. The Ljung-Box test shows that the series is independent, with no autocorrelation for lags 1 and 2. The values and residuals of the series are normally distributed, as suggested by the result of the Shapiro-Wilk test. All of these results indicate that the time-series for sex ratio at birth in Croatia from 1946 to 2011 is a result of a pure random process centered around the mean of 1.062, which can be expressed by the equation:

$$Y_{(t)} = 1.062 + e_{(t)}$$

where $Y_{(t)}$ is the value of sex ratio at birth for each year and $e_{(t)}$ is a random, normally distributed error term.

Like the previous study[25], the results of the regression analysis are not statistically significant, as shown in Table 2. There is no autocorrelation in the residuals (the value of DW test is close to its theoretical value) so the

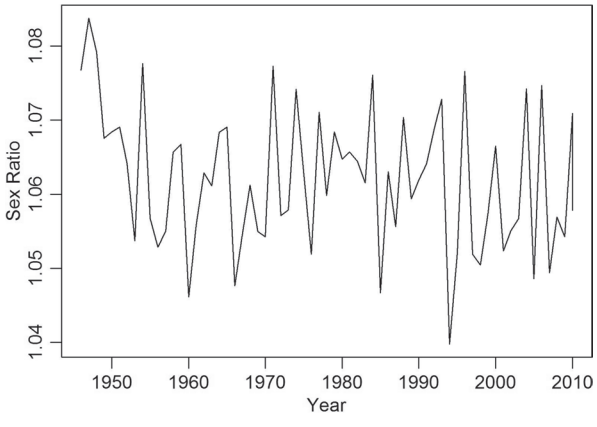


*Fig. 1. Sex ratio at birth, Republic of Croatia, years 1946–2011.*

**TABLE 2**
RESULTS FOR THE AUTOREGRESSION ANALYSIS OF THE CROATIAN SEX RATIO AT BIRTH DATA FOR THE YEARS 1946–2011

| Regression with the control of autocorrelation | | | | | |
|---|---|---|---|---|---|
| Predictor | DF | Estimate | Stand. error | t value | App. Pr>t |
| Intercept | 1 | 1.296 | 0.191 | 10.876 | <.0001 |
| Time | 1 | -0.000181 | 0.00006 | -1.961 | 0.0542 |
| Durbin-Watson test | 2.1916 | | | | |

OLS estimates were utilized. The regression was modeled with just one predictor, the time itself, to assess the existence of the temporal trend. The residuals are normally distributed (Shapiro-Wilk test 0.9857, p=0.6489), homoscedastic and linear. The results of the regression analysis suggest no linear trend in the sex ratio at birth in Croatia during the investigated period (Table 2).

## Discussion and Conclusions

The inclusion of the newer data in the analysis of sex ratio at birth in Croatia did not produce any changes in the results of both regression analysis and time series analysis from the previous study[25]. Furthermore, what seems to be the marginally non-significant decline in the sex ratio at birth over the studied period is probably influenced by the high sex ratio at birth at the beginning of this period, i.e, after the World War II. When the data for the years 1946–1949 are removed, the effect of time on sex ratio at birth is virtually non-existent.

A multitude of factors have been associated with the longitudinal change in sex ratio at birth, ranging from economic and societal to environmental and lifestyle-related. I elaborated on the economic situation and societal changes in Croatia from 1946 to 2007 extensively in my previous communication[25], yet some of the facts should be restated and reconsidered. It seems that the change of the economic system from mostly agrarian to industrialized didn't have a direct impact on sex ratio at birth in Croatia. During the studied period the GDP rose constantly thus affecting the economic prosperity of the population. These improved conditions along with better medical care and social welfare, should have resulted in a rising trend of sex ratio at birth, yet no trend has been detected. Also, the sex ratio at birth was expected to fall in the recent years due to the effects of the economic crisis. From the year 2009. onward the unemployment in Croatia has risen and the migration balance has become negative, but no change in sex ratio at birth has been documented.

The demographic transition is an unlikely factor to have impacted the sex ratio at birth. It has been hypothesized that the change in parental age and birth order could affect the sex ratio at birth. It has been found that the sex ratio in Croatia is affected by the joint high age of mother and father[27], but this effect seems too small to drive the trend in sex ratio at birth. The average number of children per female fell from 3.3 during the 1950's to 1.96 in 1991 in Croatia, which should have resulted in an increase in sex ratio at birth[28]. The increase in sex ratio at birth is well documented for low fertility societies, especially where there is a strong cultural son preference[29,30].

Different forms of psychological stress have been associated with the changes in sex ratio at birth, usually as a result of war or other disastrous events, as well as those caused by unfavorable economic and social conditions. As noted above, there is no evidence that economic stress was somehow linked to sex ratio at birth in Croatia. Also, sex ratio in Croatia seems to have been unaffected by the 1991 – 1995 war[31]. There is some support that the rising general stress levels in the population lower the sex ratio at birth, measured by the usage of antidepressants and anxiolytics[32]. Also, sex ratio at birth differs between that of a general population and of those individuals suffering from some kind of mental health issue e.g. schizophrenia[33]. The hospital rates of schizophrenia fell from 1963 to 1975 in Croatia, after which they stagnate until 1997, when they start to fall again[34]. There is an increase in the depression rates in Croatia[35] that conforms with a similar world trend[36]. The suicide rate in Croatia rose from 1966 to 1993, declining afterwards[37]. All of this data cannot be linked unequivocally and straightfowardly with the dynamics of sex ratio at birth in Croatia during the studied period. Also, the possible modulation of sex ratio at birth by assisted reproduction cannot be confirmed due to a very low number of births that were a result of some form of assisted reproduction[38].

The negative effect of obesity on both male and female reproductive physiology has been well documented. The men with a BMI greater than 25 have lower sperm concentration and sperm count[39]. In women, the obesity is associated with menstrual disorders, infertility, spontaneous abortions, worse fetus health, and diabetes[40]. Although women with a higher BMI didn't have a lower sex ratio at birth, those who gained alot of weight during pregnancy did[10]. Also, women suffering from diabetes delivered significantly more daughters[41]. In 2003, 38.11% of the Croatian population were overweight, 20.34% were obese and 43.52% had increased waist circumference[42]. These numbers are the reflections of a decades-long trend of increasing body-weight in Eastern European countries[43], although this has been a recent feature of Croatian women[44]. This trend however well documented and persistent, seems to have not impacted the sex ratio at birth in Croatia.

The most compelling explanation of the trend in sex ratio at birth has been that of chemical and other environmental agents affecting the human reproductive physiology. It has been shown that the negative changes in human reproductive physiology have been caused by pesticides[45], herbicides (DDT and chlorine compounds[46]) and industrial chemical (phtalates, polychlorinated biphenyls etc[47,48]). Although there are some differences due to different physiological responses to the chemicals, most of them affect male fetuses more, thus lowering sex ratio at birth[49]. There are several ways to be exposed to these agents, mostly by air, water and food, and the hazard is greater with individuals who are exposed to these pollutants because of professional reasons.

In Croatia, traces of PCBs, DDT and other chlorine compounds have been found in meat and fish, although the levels are in decline[50]. The pesticides have been found in fruits and vegetables, especially in imported ones[51,52], mother's milk[53], and mother's blood serum[54]. PCBs and DDT are also found in the air[55], vegetation[56], rain and snow[57] and the ground[58]. The pesticides Atrazine and Simazine are found in drinking water[59], especially near the pig farms[60]. The amounts of lead, cadmium and mercury are found in freshwater fish, sea fish[61,62] and sea shells[63], and the amounts of lead, cadmium and nickel are found in the ground[64.] Lead and cadmium are also present in human food[65]. The concentrations of these pollutants expectedly vary among these studies, peaking at the 30% of the recommended daily value[65]. Similar to the results of the obesity and diabetes studies, the presence of the environmental pollutants does not seem to modulate the sex ratio in Croatia in any way.

In conclusion, despite the presence of multiple factors known to affect the sex ratio at birth, this ratio has not been biased in Croatia in the second half of the 20th century and the beginning of the 21st century. Moreover, the sex ratio at birth appears to be the result of a random process. As stated previously, the relatively small number of observations could render the analysis unreliable. However, there are studies that utilized even smaller number of observations yet found the significant effect of the environmental factors on sex ratio at birth. These studies are usually epidemiological and clinical ones, or restricted to a specific subpopulation or geographical location[3,4,45,47]. By trying to assess the changes in sex ratio at birth on the population level, researchers, while assuring the larger sample size, include in their analyses the unaffected parts of the population, thus hindering the detection of the environmental effect on sex ratio at birth. This could explain why some studies failed to detect the impact of exogenous factors on sex ratio at birth using the population level data[31,66]. The problems stated above warn against the generalizations of »X increases/decreases sex ratio at birth« kind when trying to form the explanations for the change in sex ratio at birth on the population level, based on clinical or small-scale studies. The effects of exogenous factors on sex ratio at birth are probably small and multifactorial to be easily detected in the large national datasets.

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*D. Pavić*

*University of Zagreb, Center for Croatian Studies, Borongajska 83d, 10000 Zagreb, Croatia*
*e-mail: dpavic@hrstud.hr*

## OMJER SPOLOVA NOVOROĐENČADI U HRVATSKOJ: DOPUNA

### S A Ž E T A K

Postoje uvjerljivi dokazi da je omjer spolova novorođenčadi djelomično uvjetovan okolišnim i društvenim čimbenicima. Promjene ovih čimbenika u suvremeno vrijeme služe kao objašnjenje za smanjenje omjera spolova novorođenčadi u većini industrijaliziranih zemalja. Ovaj članak je ponovno istraživanje rezultata mojeg prethodnog rada u kojem nije utvrđen trend omjera spolova novorođenčadi u Hrvatskoj od 1946. do 2007. Dodani su podaci za godine 2008. do 2011. što nije je rezultiralo otkrivanjem značajnog trenda omjera spolova novorođenčadi pomoću regresijske analize, ni pomoću Box-Jenkinsove analize vremenskih serija. Iako su mnogi čimbenici povezani sa smanjenjem omjera spolova novorođenčadi bili prisutni tijekom istraživanog perioda (npr. izloženost okolišnom zagađenju preko hrane, zraka i vode, porast pojave pretilosti i dijabetesa, ekonomska kriza itd.), čini se da nijedan od njih nije imao mjerljiv utjecaj na omjer spolova novorođenčadi. Isto tako, moguće marginalno značajno smanjenje omjera spolova novorođenčadi može biti rezultat visokog omjera spolova odmah nakon Drugog svjetskog rata. rezultati ove studije upozoravaju protiv brzih generalizacija čimbenika za koje je utvrđeno da utječu na omjer spolova novorođenčadi u epidemiološkim i kliničkim studijama, na razini populacije.